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Field Test of Corrosion Control to Protect Asbestos-Cement Pipe

Greenwood Commissioners of Public Works, SC

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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FIELD TEST OF CORROSION CONTROL TO PROTECT ASBESTOS-CEMENT PIPE

by

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Commissioners of Public Works
Greenwood, South Carolina 29646

Grant No. R804888-01

Project Officer

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This study was conducted
in cooperation with
Commissioners of Public Works
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16. ABSTRACT

This work was performed to determine if adding zinc orthophosphate to potable water could cause an asbestos-cement pipe to be coated with zinc sufficiently to prevent asbestos fibers from entering the water.

Storage tanks and chemical feed pumps were set up at each of Greenwood's water treatment plants, and zinc orthophosphate was fed into the system at an average rate of 0.3 mg/L. Two sections of new asbestos-cement pipe were installed in such a manner as to represent a low flow and a high flow water condition and to be able to be removed for testing. Samples were periodically tested to determine the number of asbestos fibers in the water. The two pipe sections were removed and examined for the amount of zinc deposited on the surface.

Tests for pH and alkalinity showed no significant changes during the study period, but a very significant decrease of asbestos fibers in the water was observed. Photographs made with an electron microscope and energy dispersive X-ray spectra analyses showed coatings of zinc products on the two pipe samples. Corrosion of the asbestos cement pipe can be significantly reduced or prevented by the addition of zinc orthophosphate under the water quality conditions existing in Greenwood distribution system water.

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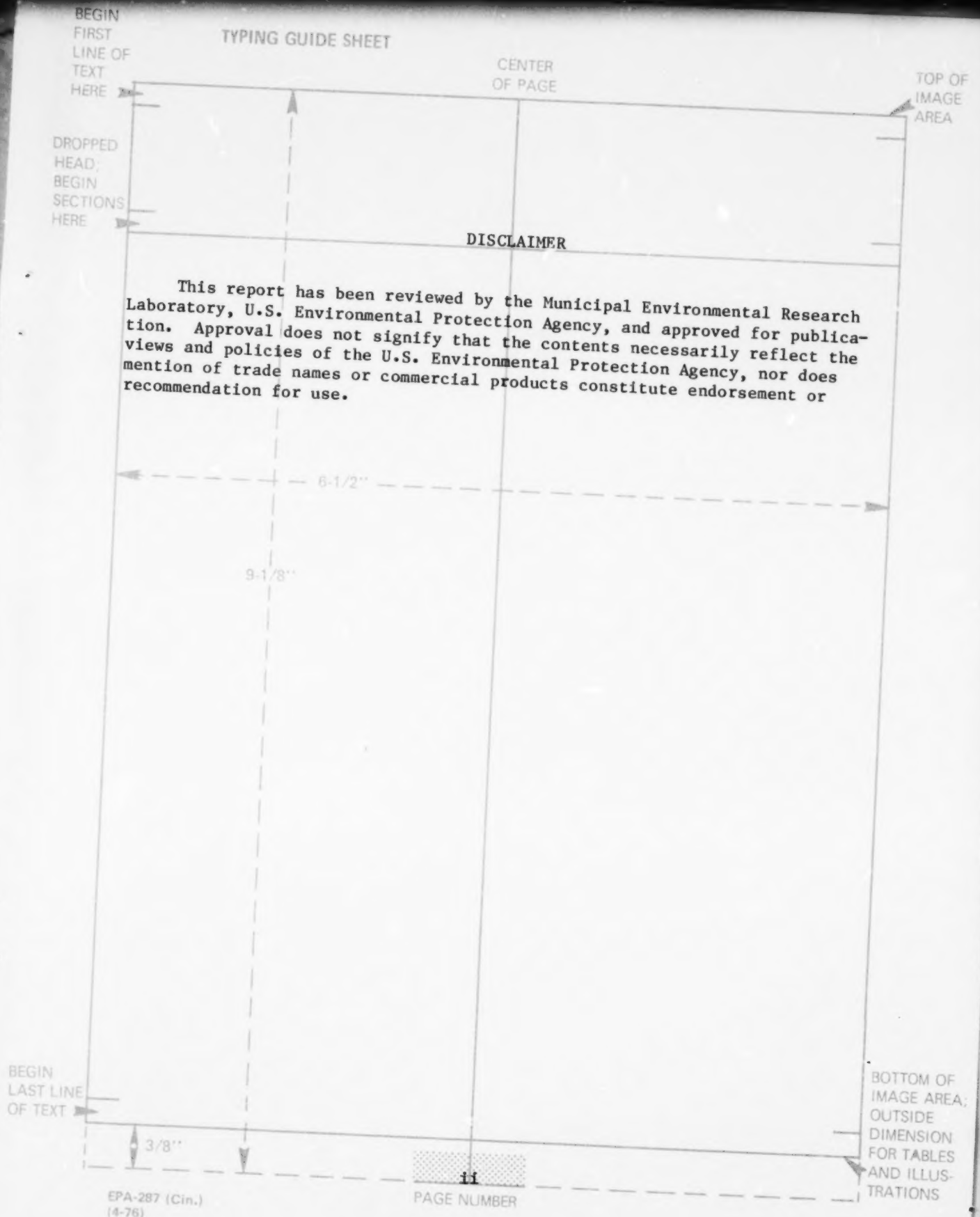
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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report describes a field study conducted to evaluate the ability of zinc orthophosphate to protect asbestos cement pipe from attack by aggressive waters and to reduce or eliminate the pick up of fibers as the water passes through asbestos-cement pipes.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

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ABSTRACT

This research program was initiated to determine if the addition of zinc orthophosphate to potable water could coat an asbestos-cement pipe with zinc sufficiently to prevent asbestos fibers from entering the water.

Storage tanks and chemical feed pumps were set up at each of the water treatment plants, and zinc orthophosphate was fed into the system at an average rate of 0.3 mg/L. Two sections of new asbestos-cement pipe were installed in such a manner as to represent a low flow and a high flow water condition and to be able to be removed for testing. Samples were periodically tested to determine the number of asbestos fibers in the water. The two pipe sections were removed and examined for the amount of zinc deposited on the surface.

Though routine tests such as pH and alkalinity showed no significant changes during the study period, a very significant decrease was shown in asbestos fibers in the water. Photographs made with an electron microscope and energy dispersive X-ray spectra analyses showed coatings of zinc products on the two pipe samples. Thus it was concluded that corrosion of the asbestos cement pipe can be significantly reduced or prevented by the addition of zinc orthophosphate under the water quality conditions existing in Greenwood's distribution system water.

This report was submitted in fulfillment of Grant No. R804888-01 by the Commissioners of Public Works, Greenwood, S. C., under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period of November 1, 1976, to November 30, 1979, and work was completed on December 14, 1979.

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SECTION 1

INTRODUCTION

The use of asbestos-cement pipe has been widespread among water distribution systems for years. Associated with the use of asbestos-cement is the corrosion or wearing away of the inside of the pipe when exposed to aggressive water. The extent of this corrosion depends on how aggressive the water is. As the corrosion occurs, calcium and asbestos fibers are released into the water. Higher pH and alkalinity result from the dissolution of calcium hydroxide and silicate in the pipe.

Because asbestos-cement (A/C) pipe is subject to corrosion in some potable water systems, concern has arisen about possible health effects of ingesting asbestos fibers eroded from the pipes, but little is known about the harmful effects of asbestos in the digestive system. No maximum contaminant level has been set for asbestos, even though the Safe Drinking Water Act sets such levels for other substances.

The water distribution system of the Commissioners of Public Works (CPW) in Greenwood, South Carolina, contains a great deal of A/C pipe, which was generally installed in the late 1940's and early 1950's. The corrosion of A/C pipe was viewed with interest in Greenwood, but it was not thought to be a problem until a customer complained of "itching all over" after showering.

Concern for the amount of asbestos fibers in potable water resulted in a request to the U.S. Environmental Protection Agency to test several samples of water from the Greenwood system. The results of the testing confirmed the presence of asbestos fibers in the water and led the Commissioners to participate in a project to determine whether a chemical could be fed into the water system to coat the pipe sufficiently to prevent further corrosion or erosion of the cement and asbestos fibers.

The study presented here examines a method of attempting to coat or line the asbestos-cement pipe with zinc orthophosphate fed into the system at the water treatment plant. Various parameters were monitored throughout the study to determine the results.

Lake Greenwood is the surface water source used by Greenwood. The raw water has a variable pH, alkalinity of 15 mg/L, total hardness of 10 mg/L as $CaCO_3$, and iron content of 0.4 mg/L. The treatment used is alum coagulation, sedimentation, filtration, pH adjustment with NaOH, and free residual chlorination. The finished water has a pH of 8.2 to 8.3, alkalinity of 20 mg/L, total hardness of 10 mg/L as $CaCO_3$, iron content of 0.1 mg/L, and free chlorine residual of 0.75 mg/L leaving the treatment plant.

A pH increase is experienced as the water passes through the distribution system. Many of the larger mains are concrete or cement-lined pipe, which causes an increase in pH before the A/C pipe in the system is reached. But the increase is not sufficient to stabilize the water, and the pH continues to rise when exposed to the A/C pipe. Exactly how severe an effect on the A/C and concrete pipe is resulting from the materials dissolving from the pipe to cause the pH change can only be determined by examining the condition of the inside of the pipe in service.

This project was the first project of this type concerned with A/C pipe. At the time this project was started the condition of A/C pipe in use was evaluated almost entirely by electron microscope asbestos fiber counts on water samples from the system. It was later learned that these fiber counts can often be influenced greatly by drilling and tapping of the pipe which leads to a false evalution of the general condition of the pipe.

SECTION 2

CONCLUSIONS

Study results indicate that the addition of zinc orthophosphate does reduce the number of asbestos fibers being released into the water.

Throughout the study period, pH, alkalinity, calcium as $CaCO_3$, and zinc were monitored. Some reductions of pH and calcium were noted about midway through the study period, but the values were near normal at the end of the study.

Counts of amphibole and chrysotile asbestos fibers in the water were determined with the aid of an electron microscope. Chrysotile fiber counts at the Canterbury location decreased during the study, except for two very high counts. The fibers in those two samples had the appearance of being coated and having been lodged in the system for some time; that is, they were not clean, newly released fibers. The 0.2-mg/L zinc concentration in this part of the system may have been instrumental in the general reduction of fibers found at Canterbury. Zinc was notably present in the coating on the fibers found in the two high counts. The chrysotile fibers found in Effie Dr. samples also showed a decreasing trend until tapping of the pipe was done near the sample site shortly before sample collection. Once the fiber counts are elevated in a low-flow situation such as Effie Dr., there can be a gradual decrease in the fiber counts over an extended period of time because the pipe does not get flushed clean. This is in contrast to the Canterbury situation, where the water flow is significantly higher and repeatedly high fiber counts did not occur.

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SECTION 3

RECOMMENDATIONS

Before zinc is applied to drinking water as a corrosion control additive, consideration should be given to the impact of zinc precipitate on water users. This could be especially significant during the initial passivation period.

If zinc is used, it should be added in a concentration adequate to protect the asbestos cement pipe.

Manufacturers' recommendations on application of additives should be followed, particularly with regard to pH in the distribution system and passivation techniques.

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SECTION 4

METHODS AND MATERIALS

EQUIPMENT

Equipment necessary to add zinc orthophosphate to the system was installed at the two water treatment plants operated by the CPW. At the Lake Greenwood Plant, which supplies approximately 90% of the system's water, a 22,700-L (6000-gal) insulated fiberglass tank and chemical feed pump were installed. At the smaller Grace St. Plant, 240-L (55-gal) drums and a chemical feed pump were used. These drums were refilled at the 22,700-L (6000-gal) storage tank. The zinc orthophosphate was injected into the system just ahead of the clearwell.

PROCEDURES

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Sampling

Samples of water were routinely taken from two locations where A/C pipe is used. Samples were checked for zinc content, pH, alkalinity, and calcium as $CaCO_3$.

Water samples were also forwarded to the EPA laboratory in Cincinnati to determine the number of asbestos fibers present.

At each of the two sampling locations (one with high-flow and one with low-flow conditions), a section of new A/C pipe was installed so that it could be removed at the end of the experiment for testing.

Installation of A/C Pipe

A 45-cm (18-in.) section of new A/C pipe was installed at the two test sites, with a 15-cm (6-in.) section being installed at Effie Dr., and a 20-cm (8-in.) section at Canterbury.

Zinc Feed Rates

Zinc orthophosphate was introduced into the system October 11, 1977, at a feed rate of 3.0 mg/L. The passivation period was terminated on October 14, 1977, short of the intended date of October 15, because of problems encountered at one of the system's larger users, a pharmaceutical company. This firm processes gauze and surgical supplies and used a cotton-filament, wound filter to remove rust or iron particles as well as other particles in the

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water. The high concentrations of zinc orthophosphate clogged the filters sufficiently to cause serious problems. The company had to change filters every 2 to 3 days during the initial periods, whereas normally, a set of filters would have lasted 6 to 7 months. The feed rate was reduced to 0.5 mg/L in an effort to ease the filter problem. Zinc was found at 0.17 mg/L at Effie Drive, the low-flow location, and it was therefore concluded that zinc was present throughout the system.

The problem continued with the filters at the pharmaceutical company, however, and on 11-21-77, the zinc feed rate was lowered to 0.3 mg/L, resulting in a decrease in the concentration of zinc at the Effie Dr. location to less than 0.1 mg/L. This rate was continued until the end of the study, although problems were still encountered with the filters.

SECTION 5

RESULTS

DATA FROM SAMPLES

Throughout the study period, various data were monitored at the low-flow (Effie Dr.) and high-flow (Canterbury) locations. The data obtained are shown on Table 1. The raw water was tested on 3-2-76 for chrysotile and amphibole fibers, with no fibers being detected. The finished water has an Aggressive Index[1] of about 10.4 to 10.5. The tendency of a water to deteriorate the structure of asbestos cement pipe has been described by the Aggressiveness Index (AI) given as

$$AI = pH + \log (AH)$$

where

$pH = -\log aH^+$ (-log of the hydrogen ion activity)

A = total alkalinity in mg/L as $CaCO_3$

H = calcium concentration in mg/L as $CaCO_3$

Waters possessing an AI in excess of 12.0 are considered to be "non-aggressive;" those where AI $\leq$ 10.0 are said to be "highly aggressive," and those with an AI between 10 and 12 are "moderately aggressive." The large values for asbestos fibers on 1-20-78 and 8-1-78 (Table 1) occurred after the A/C pipe had been tapped for a new service in the immediate area of sampling. The increase in alkalinity and calcium concentrations were also effects of the tapping operation. There are now tapping machines on the market that flush the bulk of the drilling and tapping debris out through a valve and thereby reduce tapping effects on water quality.

Figure 1 shows the interior surface of the 20-cm (8-in.) pipe magnified 900 times. The surface is smooth, and some coating resulting from zinc treatment can be identified. The average zinc concentration at this location as determined from water samples was 0.2 mg/L. Figure 2 shows the interior of the 15-cm (6-in.) pipe magnified 900 times. With a lower concentration of zinc (0.1 mg/L), much larger voids or holes can be seen on the 15-cm (6-in.) pipe than on the 20-cm (8-in.) pipe.

Table 1. Data Pertaining to Asbestos Fiber Analysis Samples at Greenwood, S.C.

Sample date	Sample location	pH	Temp. (°C)	Alkalinity (mg/L)	Calcium as $CaCO_3$ (mg/L)	A.I.*	Zinc (mg/L)	Asbestos fibers (millions of fibers/L)	
								Amphibole	Chrysotile
3/2/76	Lake Plant	8.3	X	20	7.5	10.48	-	BDL+	BDL
3/2/76	Effie Dr.	9.2	X	24	17.2	11.82	-	NSS†	0.22
10/17/77	Effie Dr.	9.0	X	29	X	X	0.3	BDL	1.10
11/21/77	Effie Dr.	9.1	X	21	X	X	0.3	BDL	0.06
11/21/77	Canterbury	8.5	X	21	X	X	0.4	BDL	0.23
1/20/78	Effie Dr.	9.1	X	22	X	X	0.08	BDL	4.6
1/20/78	Canterbury	8.5	X	18	X	X	0.2	BDL	0.13
3/17/78	Effie Dr.	9.0	X	27	14	11.58	0.1	BDL	NSS
3/17/78	Canterbury	8.5	X	20	7	10.65	0.2	BDL	BDL
4/28/78	Effie Dr.	9.1	18.3	26	15	11.69	0.09	NSS	NSS
4/28/78	Canterbury	8.5	18.3	22	9	10.80	0.20	BDL	BDL
6/2/78	Effie Dr.	8.7	25.5	25	10	11.50	0.20	NSS	2.52
6/2/78	Canterbury	8.5	25.5	21	7	10.67	0.15	NSS	3.05
8/1/78	Effie Dr.	9.2	29.4	32	17	11.94	0.08	NSS	4.0
8/1/78	Canterbury	8.7	30.0	27	11	11.17	0.10	BDL	NSS
9/22/78	Effie Dr.	8.7	X	27	13	11.25	0.07	NSS	1.05
9/22/78	Canterbury	8.5	X	21	7	10.67	0.10	NSS	1.8
11/17/78	Effie Dr.	9.0	X	35	14	11.69	0.06	BDL	0.97
11/17/78	Canterbury	8.5	X	31	10	10.99	0.20	NSS	NSS

*A.I. = Aggressive index.
+BDL = Below detection limit.
†NSS = Not statistically significant.

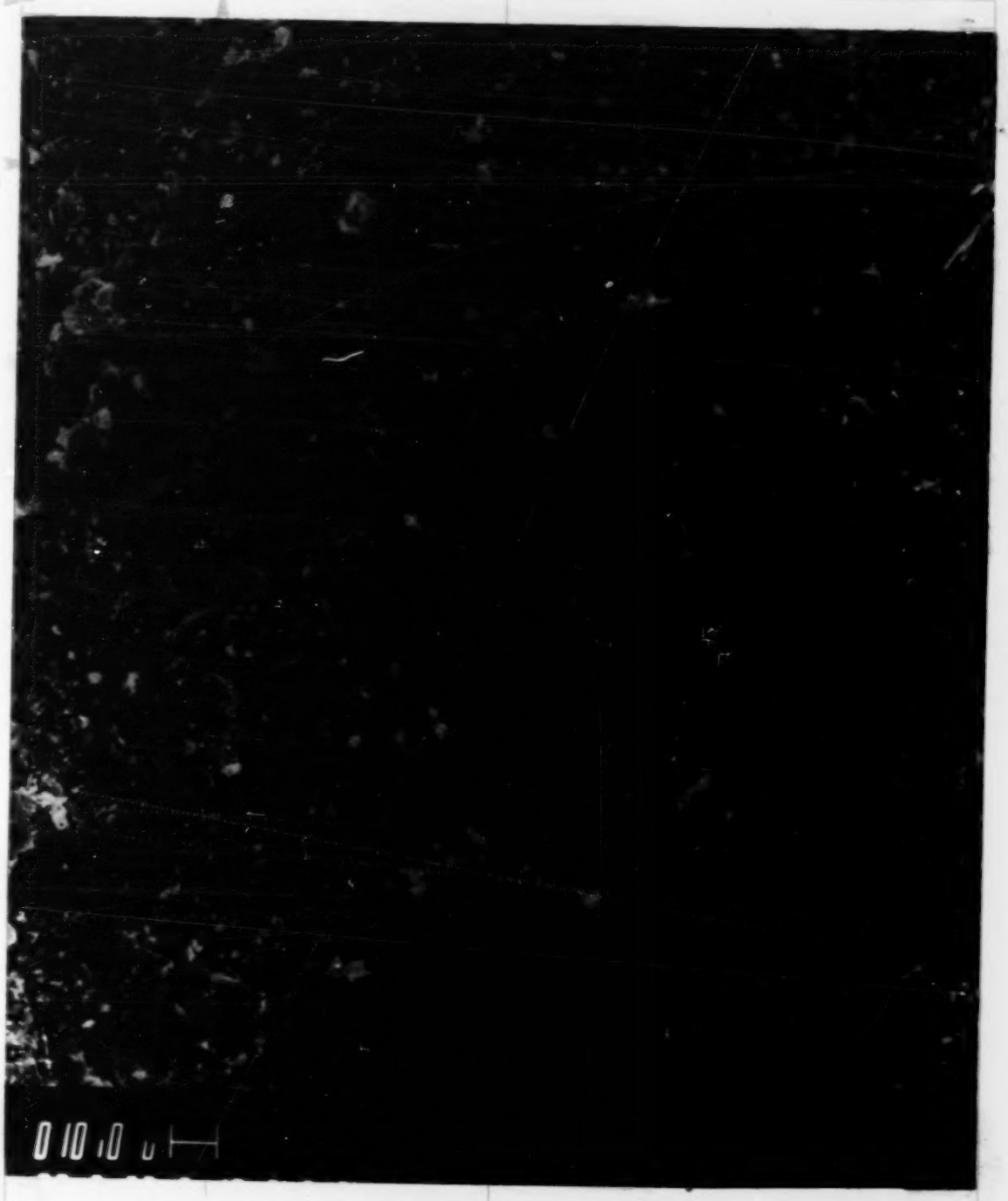

Figure 1. Interior surface of the 20-cm (8-in.) pipe magnified 900 times.

Figure 2. Interior surface of the 15-cm (6-in.) pipe magnified 900 times.

Dramatic differences are noted when the interior surfaces are magnified 3000 times. Figure 3 shows the 20-cm (8-in.) pipe, and 4 shows the 15-cm (6-in.) pipe. Regardless of location in the pipes, the 20-cm (8-in.) pipe always showed better coverage than the 15-cm (6-in.) pipe. These photographs indicate that the zinc or zinc compounds do adhere to the A/C pipe, and that to be effective, the zinc concentration must be 0.2 mg/L or greater.

Energy-dispersive, X-ray spectrometric elemental analyses were made on the surfaces of the two test pipes and for comparison with a new, unused piece of pipe. Figure 5 shows the analysis on the unused pipe, and as expected, the only large peak shown was calcium. Figure 6 shows high peaks for iron and zinc on the 20-cm (8-in.) pipe. The low peak for calcium could indicate that the pipe is well protected and the calcium is masked at this location. Figure 7 shows high silica and calcium peaks and a low zinc peak, again indicating that the low zinc concentration of 0.1 mg/L in the 15-cm (6-in.) A/C pipe is not adequate to provide a protective coating -- certainly not as effectively as 0.2 mg/L.

In the energy-dispersive, X-ray spectrometric analyses, the peak size for zinc and iron varied with location in the pipe. A comparison of these peaks from the 15-cm (6-in.) and the 20-cm (8-in.) pipes showed, however, that the highest peaks of the 20-cm (8-in.) pipe were always higher than the highest peaks of the 15-cm (6-in.) pipe, and the lowest peaks of the 15-cm (6-in.) pipe were always lower than the lowest peaks of the 20-cm (8-in.) pipe. The results for the iron peaks suggest that iron in the water provides a partial protective coating to the A/C pipe in this system.

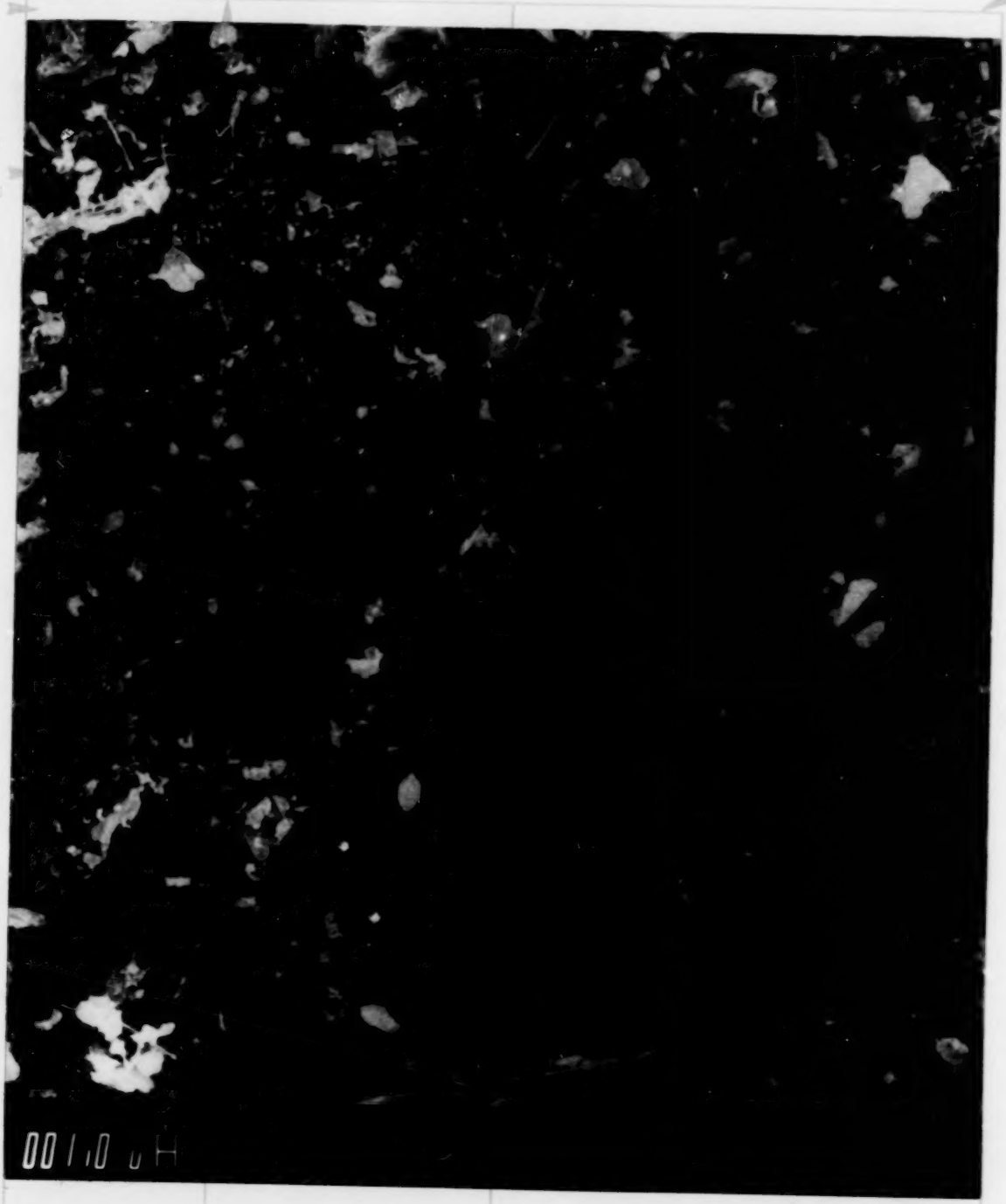

Figure 3. Interior surface of the 20-cm (8-in.) pipe magnified 3000 times.

Figure 4. Interior surface of the 15-cm (6-in.) pipe magnified 3000 times.

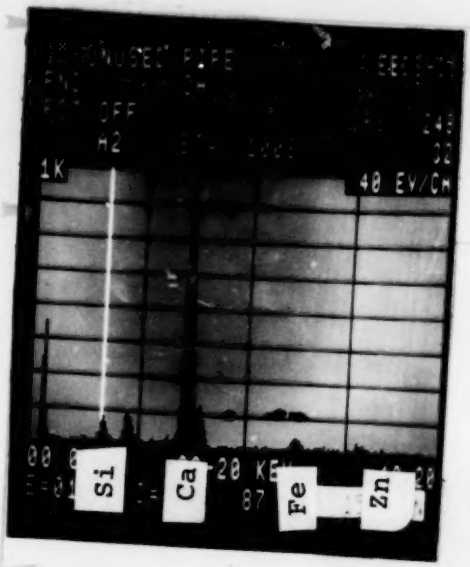

Figure 5. Energy-dispersive, X-ray spectrometric elemental analysis of the unused pipe.

Figure 6. Energy-dispersive, X-ray spectrometric elemental analysis of the 20-cm (8-in.) pipe.

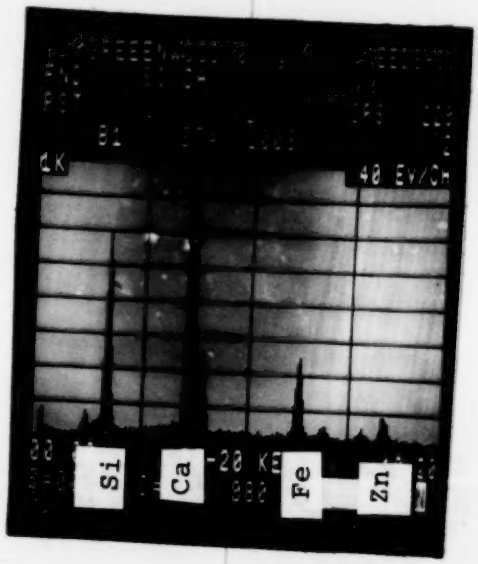

Figure 7. Energy-dispersive, X-ray spectrometric elemental analysis of the 15-cm (6-in.) pipe.

SECTION 6

DISCUSSION

Varying results were noted in the study as the concentration of zinc orthophosphate was adjusted. Initially during the passivation period, a dosage concentration of 3.0 mg/L appeared to be sufficient. However, as the dosage concentration was reduced to 0.4, 0.3 and 0.25 mg/L, the zinc orthophosphate became less effective in stopping the corrosion. The optimum dosage concentration seems to have been 0.4 mg/L for the Greenwood system.

At the Canterbury location, where the zinc concentration was high enough to be effective, the zinc appeared to be responsible for the virtual elimination of asbestos fibers, except in what appeared to be a break-away of lodged fibers that resulted in the two high fiber counts. Experiments performed at the Drinking Water Research Division, Cincinnati,[2] have also shown that zinc concentrations of 0.3 mg/L or more will protect A/C pipe when used in water of similar quality to Greenwood. As for the Effie Dr. results, where the zinc concentration was not high enough to be very effective except very early during the treatment period, forming any conclusions is difficult, and the possibility remains that most of the asbestos fibers found in this area have always resulted from drilling and tapping operations.

It is necessary to sort out what portion of the asbestos fibers found in water samples are the result of pipe degradation and what portion resulted from drilling and tapping activities. The effect of drilling and tapping can be long-term in a low-flow, dead-end type of situation.

An examination of old A/C pipe specimens from the Effie Dr. area and elsewhere in the system would help decide whether the A/C pipe is or is not being attacked by the Greenwood water and if it is, to what degree. Whenever any connection plugs or sections of A/C pipe are removed from the distribution system, they should be examined to evaluate the degree of deterioration, if any.

Although this project was directed toward A/C pipe corrosion control, the addition of zinc orthophosphate affected other piping materials. A reduction of water color complaints occurred at previous trouble spots after the zinc orthophosphate treatment was employed.

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